SEG/KOC
JOINT WORKSHOP

Global Single Sensor Acquisition and Processing—Past, Present and Future

The Regency Hotel
Kuwait City, Kuwait
3–6 December 2012

SEG

شركة نفط الكويت
Kuwait Oil Company
إحدى شركات مؤسسة البترول الكويتية
A Subsidiary of Kuwait Petroleum Corporation

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Global Single Sensor Acquisition and Processing—Past, Present and Future

The revolution in acquisition equipment and processing technology has put the industry in a new position to increase sampling and fold to levels previously unimaginable. This raises many questions regarding optimum use of single sensor single source technology for the future. This workshop will share the cross industry experiences of current practitioners from around the globe and address many of these outstanding questions. Attendees can expect lively discussions and informed debate on all topics related to this emerging technology. In addition, attendees will have the opportunity to visit a 220,000 channel 3D seismic crew operating in north Kuwait.

The Society of Exploration Geophysicists (SEG) and Kuwait Oil Company (KOC) are proud to promote this opportunity for knowledge exchange in Kuwait City. On behalf of SEG, KOC and the Organizing Committee, we are honored to welcome everyone attending the "Global Single Sensor Acquisition and Processing—Past, Present and Future" workshop and we wish you a pleasant stay in Kuwait City.

GENERAL INFORMATION

Field Trip

On December 3rd, we are organizing a field trip to the highest channel count 3D single sensor crew operated by KOC in north Kuwait.

After welcoming the attendees, KOC management will set the visit in motion with a tour describing the major steps of the acquisition process with displays of the major equipment components.

The highlight of the visit will be a Barbecue lunch served at a purpose-built royal tent for all to enjoy the pleasant December weather.

Gala Dinner

The KOC chairman and senior management will host a gala dinner on December 5th. All participants will have the opportunity to discover the legendary Arab hospitality in a relaxed ambience whilst savoring traditional delicacies.

Soothing Kuwaiti music and lively discussions will fill the atmosphere of a night for us all to remember.

Please remember to:

- **Bring suitable clothes for the season (mild days and fresh nights). Hiking boots are recommended for the field trip.**
- **Medications (if any) with instructions**

TUESDAY, DECEMBER 4

8:30–8:40 **Welcome by Kuwait Oil Company (KOC)**

Morning Session — On-shore Case Histories- I

Session Chairs: Khalid Al-Mulla (KOC) & Jean-Jacques Postel (CGGVeritas)

8:45–9:15 **KEYNOTE: What is the Role of Single Sensor and Broadband Technology in Exploration and Development?** Peter I. Pecholcs (Saudi Aramco), Co authored by Adel El-Emam (KOC)

9:15–9:40 **Advances in Dense Sampling Seismic Acquisition but What is the Bottle Neck: Sources or Receivers?** Said Mahrooqi (PDO)

9:40–10:05 **The Jordan-Risha High Productivity 3D Survey,** Jack Bouska (BP)

10:05–10:25 **BREAK**

10:25-10:50 **Observations from a Point Source, Point Receiver Surface Seismic Acquisition,** Salva Seeni (QP)

10:50–11:15 **Post-stack Interpretation and Inversion Lessons Learned: A Broadband Full Azimuth Land 3D Seismic Case Study from Saudi Arabia,** Luis Giroldi (Saudi Aramco)

11:15–12:00 **DISCUSSION**

12:00–13:00 **LUNCH**

Afternoon Session — On-shore Case Histories- II

Session Chairs: Adel El-Emam (KOC) & John Quigley (WesternGeco)

13:00–13:30 **KEYNOTE: Single Sensors — Impact on Survey Design and Seismic Operations,** Dave Howe

13:30–13:55 **Single-sensor HD-3D in China: Case Studies from MEMS-based Accelerometers,** Denis Mougenot (Sercel)

13:55–14:20 **Single-Sensor Technology, Story of Success from Kuwait,** Jarrah Al-Jenaie (KOC)

14:20–14:40 **BREAK**

14:40–15:05 **3D Point Source and Point Receiver Recording in a Complex Thrustbelt Environment – A Case Study,** Peter Van Baaren (WesternGeco)

15:05–15:30 **Scope for Improvement in Single Sensor Data Processing in Kuwait: An Interpreter's View,** Raju Arasu (KOC)

15:30–16:00 **DISCUSSION**

WEDNESDAY, DECEMBER 5

Morning Session — Acquisition & Processing Challenges- I

Session Chairs: Jack Bouska (BP) & Saif Ali Al Mesaabi (ADNOC)

8:30–9:00	**KEYNOTE: Acquisition Challenges,** Norm Cooper (Mustagh Resources)
9:00–9:25	**Pros and Cons of Point-Source-Point-Receiver Acquisition Yesterday, Today and Tomorrow,** Julien Meunier (CGGVeritas)
9:25–9:50	**Acquisition Challenges — WesternGeco Experience,** John Quigley (Western-Geco)
9:50–10:10	**BREAK**
10:10–10:35	**Rayleigh Wave Inversion for the Near-Surface Characterization of Shallow Targets in Kuwait,** Anna Glushchenko (Schlumberger)
10:35–11:00	**Suface Wave Analysis, Modeling and Inversion with Higher Modes,** Daniele Boiero (WesternGeco)
11:00-11:25	**Near-surface Characterization through Simultaneous Joint Inversion of Surface Waves and Refracted Waves,** Wael Zahran (KOC)
11:25–12:00	**DISCUSSION**
12:00–13:00	**LUNCH**

Afternoon Session — Acquisition & Processing Challenges- II

Session Chairs: Ghassan Rached (KOC) & Peter I. Pecholcs (Saudi Aramco)

13:00–13:30	**KEYNOTE: Processing Challenges from Hi-density Land WAZ Surveys,** Nigel Benjamin (CGGVeritas)
13:30–13:55	**Processing Challenges — WesternGeco Experience,** Peter Vermeer (WesternGeco)
13:55–14:15	**BREAK**
14:15–14:40	**Challenges on Ultra High-Density Seismic Survey: Array-Free Processing,** David Le Meur (CGGVeritas)
14:40–15:05	**Observations from a Point Source, Point Receiver 3D VSP Acquisition,** Philippe Herrmann (CGGVeritas)
15:05–16:00	**DISCUSSION**

THURSDAY, DECEMBER 6

Morning Session — Industry Trends, New Technologies & Way Forward

Session Chairs: Daniel Van Hulle (CGG) & Jerrah Al-Jenaie (KOC)

8:30–9:00	**KEYNOTE: Toward Million Single Channel Acquisition,** H. J. Hwang (Shell)
9:00–9:25	**The Applications of Single-Sensor Technology in Shale Gas Plays,** Mark Egan (WesternGeco)
9:25–9:50	**Recording Instruments and Source Control — What Is Viable Today in Single Sensor Acquisition and What Can We Expect Tomorrow,** Bob Heath (ISEIS Co)
9:50–10:10	**BREAK**
10:10–10:35	**Single Sensor Versus Geophone Group — Field Test Results,** Jack Caldwell (Geospace Technologies)
10:35–11:00	**Which Point-receiver? From Geophones to GPS-driven 3C MEMS-based Accelerometers,** Denis Mougenot (Sercel)
11:00–11:25	**The Application of Uncoupled Sensors to Seismic Exploration,** Elio Poggiagliolmi (KFUPM)
11:25–12:00	**DISCUSSION**
12:00–13:00	**LUNCH**
13:00–15:00	**OPEN DISCUSSION session with Keynote Speakers**

PETER I. PECHOLCS

Peter I. Pecholcs, senior geophysical consultant, Saudi Aramco, received his Master of Science degree in Applied Geophysics from Columbia University in 1982 and did graduate work at both Columbia University in 1983 and University of Hawaii from 1988-1991. Peter has worked as a research geophysicist for SOHIO Petroleum from 1983 to 1988 and as chief hydrologist for the USGS on the island of Tinian before joining Saudi Aramco as a research geophysicist in 1992. In 2001, Peter joined the Geophysical Data Acquisition Division. His area of expertise includes near-surface model construction, statics, depthing, signal processing, noise attenuation, and seismic acquisition. Peter has presented and published on these subjects in geophysical conferences and workshops and has been an invited speaker on land seismic topics. His current interests include high-productivity broadband full-azimuth integrated studies from acquisition to processing to inversion to rock mechanics.

ADEL EL-EMAM

Adel El-Emam is a Senior Specialist Geophysicist with Kuwait Oil Company, Exploration Group. He has a BSc. in Geology from the University of Cairo, 1975 and MSc. in Geophysics "Attenuation of Seismic Waves" from the University of Pittsburgh, 1983. Adel has more than 30 years of experience with local and international oil companies.

He joined KOC in 1995; currently he is Geophysical Advisor responsible for seismic data acquisition and processing. He is also an advisor to Deputy Managing Director, KOC. He previously held the position of Data Processing Department Manager with GPC, Cairo, Egypt. Adel presented and published several technical papers in local and international conferences. He has been awarded "Best Poster Presented at 2005 SEG Annual Meeting." He is an active member of SEG, EAGE and SPE where he has chaired several technical sessions and acted as technical reviewers for the SEG and EAGE.

ABSTRACT

What Is the Role of Single Sensor and Broadband Technology in Exploration and Development?

Peter I. Pecholcs, Saudi Aramco and Adel El-Emam, Kuwait Oil Company

Saudi Arabia and Kuwait have a long history of using seismic technology in their exploration and development programs, leading to the discovery and enhanced production of some of the largest oil and gas fields in the world. Today, in seismic exploration we share the common goal of recording both unaliased signal and noise wavefields. To achieve this goal requires very high-channel count recording systems and high vibroseis productivity methods. In Saudi Arabia, three full-azimuth 3D surveys have been acquired using a 100,000 channel single sensor recording system and in Kuwait, the second full-azimuth survey is being recorded with the first 210,000 channel acquisition system.

In both countries, the hydrocarbon reservoirs lie below a very complex geologic overburden with varying surface consistent and non-surface consistent (buried) velocity anomalies. This complex overburden scatters the near- surface guided wave modes and multiples and masks the primary reflections.

In the past, with lower channel recording systems, the best approach to deal with this surface related noise was to use large in-field source and receiver arrays to improve the signal-to-coherent noise ratio at the expense of the signal bandwidth. These wavefields include scattered noise that was considered part of the inherent random noise in the data. Today our approach is to record with smaller source and receiver arrays, or even point sources and sensors, forming a dense full-azimuth recording grid. What was considered random noise in the past is now sampled properly and seen to be coherent. This complex coherent scattered wavefield can now be modeled and subtracted from the seismic data with some success, although more work on optimizing this methodology is needed.

This paper presents the lessons learned in Saudi Arabia and Kuwait from different 3D surveys acquired over the past 15 years using high source and receiver density survey designs. It will also discuss the 3D processing workflows that were developed to handle these very large pre-stack datasets, and the methods used to optimize the coherent noise attenuation.

DAVE HOWE

After starting his career as an Observer with Seismograph Service Ltd, Dave spent 30 years as a Seismic Acquisition Specialist for BP.

He has considerable experience with introducing new technologies and acquisition methods, having been Senior Observer operating the first digital telemetry recorder in Europe, Operations Geophysicist for the first 10-streamer marine 3D, Technical lead for BP's 'Life of Field' permanent seabed installations, Developer of the Independent Simultaneous Sources (ISS) method — and, most recently, Designer of ISS surveys using autonomous nodes and single sensors.

Now retired from BP he is able to take a step back from the responsibilities of continuing operations and take a more detached view of development trends with single sensors.

ABSTRACT

Single Sensors — Impact on Survey Design and Seismic Operations

Dave Howe (formerly Operations Geophysicist with bp. Now retired.)

Summary

Now that technology can provide the survey designer almost unlimited numbers of single sensors, there is no longer any need for compromise between recording aperture, line spacing and sensor spacing. But will a complete grid of finely spaced receivers become the standard for all future surveys?

The intense field effort needed to lay out such dense recording spreads may not always be economically worthwhile or environmentally acceptable.

More measurements and finer sampling can always be expected to improve a seismic dataset. In the past the survey designer's sampling ambitions were constrained by the number of channels available, but with no effective limit to the channel count he will need another way to decide when he has enough receivers to provide fit-for-purpose data.

To illustrate the range of possible uses of single sources and single receivers this talk will include details of a recent survey using a node design with a very coarse grid of point receivers and a fully-sampled source grid, which is at the opposite end of the spectrum from the ultra-dense single sensor surveys that will be presented by others.

This node survey design consisted of a coarse grid of receivers spaced at 250 m over the entire survey area, with source points on a 50 m x 50 m grid also covering the entire survey area apart from unavoidable omissions.

Each receiver consisted of a well-buried point receiver, with an autonomous OYO-Geospace GSR recorder. These receivers were laid out and left to record data continuously for up to three weeks, with no real-time monitoring.

A fleet of vibrators acquired a full 50m x 50m grid of single source points, using the independent simultaneous source (ISS) technique.

New recording and new source techniques often add extra complexity to seismic operations but this ISS and node technique led to a dramatic simplification of the field operations. To get the full benefit of this efficient technique required a major re-design of the way the seismic crew operated. After deliberately stopping all non-essential work and creating a camp that could be moved every day, a very small, highly trained and motivated crew with very little field equipment were able match the high productivity of a much larger crew, with greatly reduced environmental impact and significantly lower HSE risks.

This application of single-sensor, single-source technology has such a light environmental impact that it could possibly enable access to areas where traditional seismic surveys would not be permitted.

NORM COOPER

Norm Cooper received his BSc with a major in Geophysics from the University of British Columbia in Canada in 1977. After a short experience with the mining industry he joined Amoco Canada Petroleum Company. With Amoco he received additional training in many aspects of acquisition and processing and gained much experience as an interpreter. In 1981 Norm moved to Voyager Petroleums Ltd. There he became more directly involved with seismic field operations and program design in addition to his normal interpretation and exploration responsibilities. In 1983 Norm founded Mustagh Resources Ltd. Since then he has been very active in geophysical consulting, survey design, and general exploration.

Mustagh has designed over 3000 seismic projects spanning more than 50 countries. Norm and Mustagh have provided services to 430 clients.

Also, over the years, Norm has developed a series of courses focusing on fundamental seismic principles, acquisition and program design. Teaching now constitutes about 40% of Mustagh's business. More than 2000 participants have attended Norm's courses.

Norm is a member of the CSEG, SEG, ASEG, CAGC, APEGGA, CSPG, and CWLS. He has served two terms as a director of the CAGC, has been a vice-president of the CSEG, was a director of Genesis Exploration and has served on numerous committees serving the geophysical community. He has received the CSEG Meritorious Service Award and several Best Paper awards.

ABSTRACT

A Few Words of Caution When Using Single Sensors

Norm Cooper, Mustagh Resources Ltd.

Summary

Single sensor recording may offer some advantages in data quality. However, in the rush to use this technology, some geophysicists have perhaps overlooked some fundamental seismic principles. In this short presentation, we will endeavor to review some basic concepts in spatial sampling of both signal and noise. We will compare the use of analog arrays versus single sensors.

Ultimately, we will conclude that the benefits of single-sensor recording may remain area and prospect dependent.

Introduction

Some proponents of single-sensor recording have not only extolled the benefits of some of the newer technology, but have also chosen to berate the application of arrays of analog sensors. Often, both arguments are overstated or distorted to suit the position of the speaker.

In general, surface source and receiver intervals are chosen to provide adequate sampling of apparent wavelengths of reflected and diffracted signals. However, few seismic programs have the luxury of recording only desired signals. Our data comes mixed with a variety of noise modes that can exhibit a wide range of wavelengths, often far beyond the spatial spectrum of desired signals. Noise such as ground roll generally contains longer wavelengths, usually overlapping the shorter wavelengths of desired signal. But chaotically scattered surface waves create a broad-band noise that includes some very short wavelengths. Such noise requires a small spatial sampling in order to avoid aliasing of noise modes into desired signal bandwidths.

In the latter case, conventional recorded trace intervals may not be sufficient. In the past, analog arrays have served the function of providing spatial sub-sampling of such noise modes. In each project, a decision must be made as to whether an array of analog geophones adequately serves this need, or if tightly-spaced single-sensors are more effective. The pros and cons of each option are discussed in this presentation.

Furthermore, the type of single sensor to be used should be carefully considered. There have been remarkable advances in receiver technology with MEMS sensors and low-frequency recording. However, there are some acquisition scenarios where such sensors are not appropriate. GACs (Geophone accelerometers) may provide an attractive option in areas where impact of water droplets, flying insects or blowing sand grains might trigger high-amplitude spikes due to the low inertia of MEMS

sensors. We will show examples where single sensor recording has resulted in noisy traces that make processing more difficult.

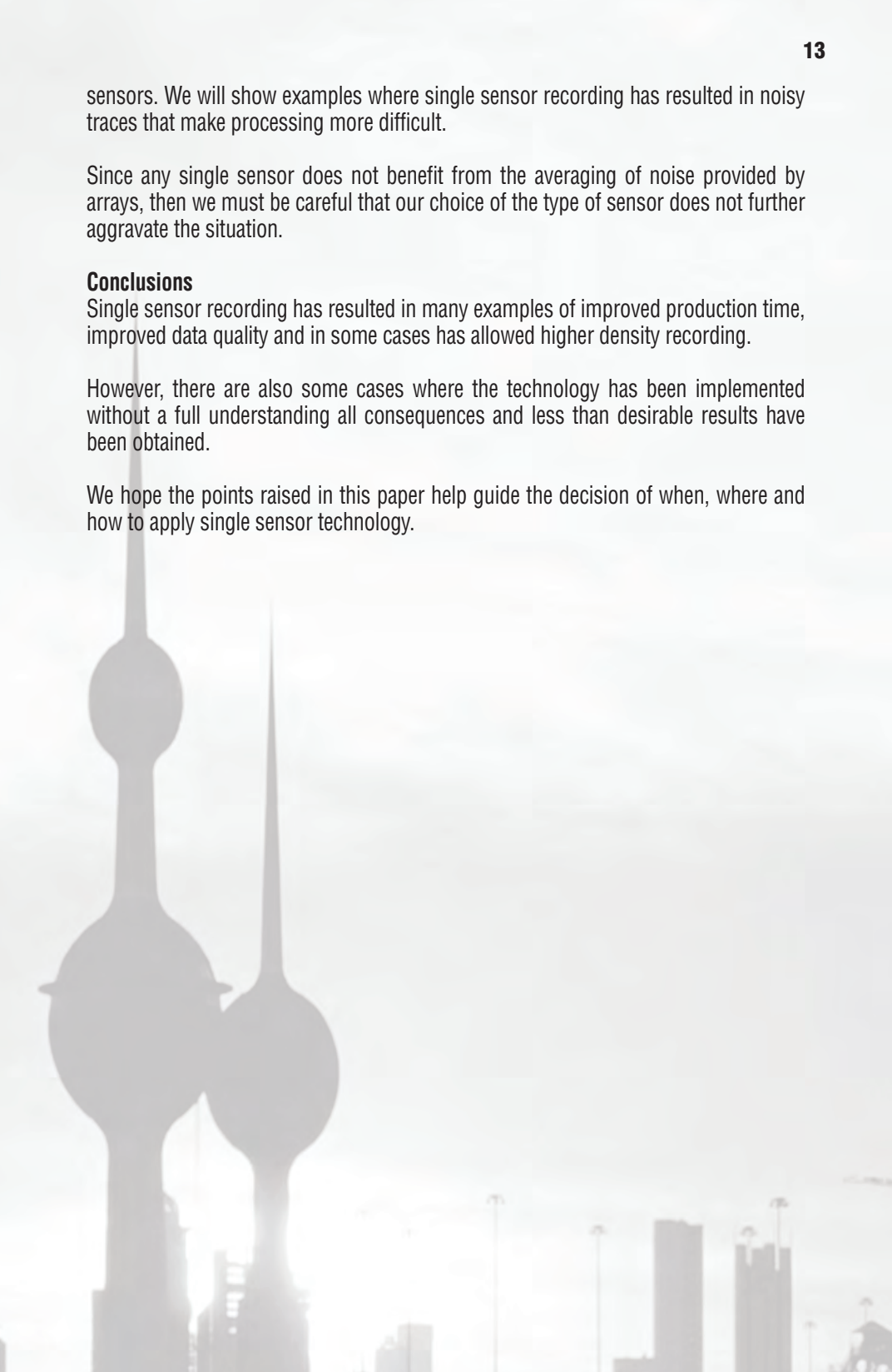
Since any single sensor does not benefit from the averaging of noise provided by arrays, then we must be careful that our choice of the type of sensor does not further aggravate the situation.

Conclusions

Single sensor recording has resulted in many examples of improved production time, improved data quality and in some cases has allowed higher density recording.

However, there are also some cases where the technology has been implemented without a full understanding all consequences and less than desirable results have been obtained.

We hope the points raised in this paper help guide the decision of when, where and how to apply single sensor technology.



NIGEL BENJAMIN

Nigel Benjamin received his BSc in Geology and Oceanography from the University of Wales, United Kingdom, in 1979. A career, now over 33 years, was begun with Geophysical Service International (GSI) in London and has, almost exclusively since, been related to Land and Shallow-Water seismic data processing in the Middle East region. Spells of field geophysicist and crew supervisor in Saudi Arabia were followed by processing supervision in London for clients including the Kuwait Oil Company (KOC) and Petroleum Development Oman (PDO), amongst others. In 1986 Nigel accepted the position of 3D Processing Supervisor and Deputy Centre Manager at the dedicated processing centre for PDO in Muscat where he is still resident. After leaving GSI (then Halliburton Geophysical Services) in 1994 Nigel joined Compagnie Générale de Géophysique (CGG) to become the Technical Supervisor for the PDO processing operation. From 2008 Nigel has been the Middle East regional Geophysical Advisor for CGGVeritas and has played the major role in overseeing changes and developments required for Wide-Azimuth data processing. This includes supervision of operations in Muscat for PDO, at an Open Centre in Muscat for external clients, in Al-Khobar, Saudi Arabia, as well as consultancy in operations for Qatar and Abu-Dhabi clients. Nigel has contributed to many research developments and co-authored many papers including, adaptive ground-roll attenuation, acquisition imprint filtering and improved deconvolution on land data.

Nigel is married with 2 adult daughters studying for their PhD and MSc respectively at the University of Durham, United Kingdom. Outside of geophysics, his interests include philately and big-game sport fishing. He is a member of the EAGE.

ABSTRACT

Processing Challenges From High-Density Land Wide-Azimuth (WAZ) Surveys

Nigel Benjamin, CGGVeritas

Introduction

Modern acquisition methods with high-density source and receiver sampling, finer intervals, and point recording, open many doors of opportunity that were previously closed. This paper will try to document some of the challenges faced by processors from these data and also some examples of the solutions and excellent results currently being obtained. It results from over 5 years experience with surveys of this nature within the Middle East, predominantly from Oman. It is intended more as a catalogue of the issues for workshop discussion and debate rather than a comprehensive analysis of any one particular subject.

The importance of the processing effort should not be understated as it is the processing that transforms raw field data into meaningful and valuable products for exploration and development. However simply acquiring more data does not necessarily guarantee success. Often the processor feels that acquisition is more concerned with quantity and productivity rates rather than the quality of seismic traces for processing. The so-called 'new generation' seismic creates issues in 2 broad categories.

Logistical Issues

The first category is logistical and is mostly associated with the volume and density of information acquired. In real terms a modern survey can now represent a 2500 fold increase of information per unit area compared to 25 years ago. However the step changes that first began 5 years ago are still continuing unabated at an accelerated rate. This places huge demands on the technology, infrastructure and research for processing which struggles to keep pace. Some of the logistical issues are briefly listed below:

- Data volumes, disc storage, data management, back-up, security ...
- Quality control – what to do with 70 billion traces ?
- Testing – do we still need to test ?
- Overall capacity of computer systems and system management …
- IT infrastructure – networks, I/O, job management, job sizes …
- Software – 3D algorithms for pre-stack, memory, efficiency …
- Massively parallel computation – surface consistency, tomography, 5D interpolation …
- The cost of failure or re-run.
- Domain changing, sorting …
- Client expectations which are generally better, faster, cheaper …

Geophysical Issues

The second category are the geophysical issues. Again the list below is not exhaustive but highlights the main areas :

- Near Surface description – the key for improvement in many Land areas lies with a more accurate description of near-surface seismic properties and attributes.
- Noise – noise on the acquired field data, in its myriad forms, is the scourge of the signal processing effort. Modern data is undoubtedly 'noisier' than vintage data acquired with field arrays. But surgical separation of reflected signal from all the unwanted signals is still a very challenging topic.
- Deconvolution, wavelet stability and surface-consistent solutions – still a major issue and a 'work in progress'.
- Statics and velocities – there is now a requirement for more accurate kinematic corrections that vary spatially in 3 dimensions. Ability to pick these accurately, on huge volumes of data, demands automated methods. But these are severely hampered by noise.
- Imaging – time or depth ? Time, with its more simplistic assumptions, still has a role to play but it is depth that must be the ultimate choice. There are many choices to make and issues involved.
- Attributes – how best to focus on the wealth of information that can be delivered from high density WAZ surveys.

Processing Solutions

After detail of the problems and challenges we must acknowledge the many excellent solutions that have been developed over the past 5 years. Within CGGVeritas these have included the following which are in routine daily use on WAZ projects :

- First arrival tomography handling many billions of picks.
- Frequency dependent noise attenuation
- Adaptive Groundroll and Guided-Wave modeling and subtraction
- 3D FX-Y projection filtering
- Beyond aliasing Tau PX-PY linear noise filtering
- Simultaneous surface consistent deconvolution and amplitude corrections.
- Monte-Carlo residual statics
- 3D high-resolution Radon modeling
- Wave equation interbed multiple modeling and subtraction.
- High density residual moveout (RMO) and anisotropy estimation

Conclusions

The challenges are many but only sustained and increased financial investment in IT infrastructure, R&D, and human resources will allow processing to keep pace and to expedite delivery of some of the solutions needed.

H. J. (JAY) HWANG

Jay joined Shell in 1986. He has a BS in geology and a PhD in geophysics. Jay held various technical and supervisory positions in Geophysics, exploration, business development, and technology organizations.

Jay Hwang is currently R&D Team Leader for Seismic Acquisition and Non-linear Method. Prior to this position he was Manager of Future/Emerging Technology in Shell Unconventional Oil. Before that, Jay was the Global Deep-water R&D Manager.

ABSTRACT

Toward Million Single Channel Acquisition

By Dirk Smit, VP Exploration Technologies, Royal Dutch Shell

The E&P industry is increasing its exploration activities on land in desert and swamp environments, including deep and tight, non-amplitude supported plays in non-calibrated basins. Seismic technology is key to de-risk these prospects. Current acquisition technology is limiting the quality of seismic on land for a number of reasons and a leap forward in seismic fidelity is required.

The lower quality of onshore seismic data results primarily from near-surface complexities and ground roll. Current survey designs allow only for limited attenuation of these effects, with the remaining surface noise negatively affecting the efficiency of subsequent data processing. Final images suffer from high noise levels, poor amplitude stability, and narrow bandwidth. Further derivative products, such as inversions, also are negatively affected and have limited value in constraining reservoir uncertainties. Similarly, reservoir responses observed from time-lapse seismic are shielded by high noise levels, limiting its value for reservoir surveillance.

Mathematical modeling demonstrates that to obtain data fidelity comparable to current deep marine seismic, data sampling and quality needs to be improved by increasing the frequency bandwidth to include very low frequencies and by increasing the single channel count to order 1 million.

For producing reservoirs, high-quality dense sampling needs to be made available as well to enable accurate permanent reservoir monitoring.

Current seismic survey designs show dense receiver sampling inline but coarse receiver sampling cross-line. This type of geometry does not allow spatial 3D filter techniques. Single sensors in combination with digital array filtering offer full flexibility in layout geometries designed specifically for a local surface noise type. Current cabled systems using in-field analog summation cannot achieve this flexibility. Also, better noise attenuation is achieved than from an analog summation with the same number of sensors. With this technology, statics can be processed to better pre¬serve the high-end of the recorded bandwidth.

Shell's vision on the future of single-channel acquisition is presented and it is described how Shell has taken the initiative to invest in the development of two onshore single-channel seismic systems that can be scaled to achieve very high densities.

HP/Shell prototype Receiver Sensor Node

The first system is developed in partnership with Hewlett-Packard and consists of a low-weight, wireless single-channel seismic system that is ideal for use in difficult terrain but can also be cost-effectively scaled to a million channels in desert setting. The second is in partnership with PGS to develop a low-weight, optical, single-channel system that uses only light to transmit data through optical fiber, much lighter than traditional wires. Given that individual channels do not need power in the field also makes this system ideally suited for permanent reservoir monitoring.